

MEASUREMENT OF THE HADRONIC PHOTON STRUCTURE FUNCTION F_2^γ AT LEP2

R. J. TAYLOR

*Department of Physics and Astronomy, University College London,
Gower Street, London WC1E 6BT, United Kingdom
E-mail: rjt@hep.ucl.ac.uk*

The hadronic structure function of the photon $F_2^\gamma(x, Q^2)$ is measured as a function of Bjorken x and of the factorisation scale Q^2 using data taken by the OPAL detector at LEP. Previous OPAL measurements of the x dependence of F_2^γ are extended to an average Q^2 of 767 GeV². The Q^2 evolution of F_2^γ is studied for $11.9 < \langle Q^2 \rangle < 1051$ GeV². As predicted by QCD, the data show positive scaling violations in F_2^γ . Several parameterisations of F_2^γ are in agreement with the measurements whereas the quark-parton model prediction fails to describe the data.

1 Introduction

Much of the present knowledge of the structure of the photon has been obtained from measurements of deep-inelastic electron-photon scattering at e^+e^- colliders. With the high statistics and high electron energies at LEP2 it is possible to study F_2^γ at $Q^2 > 1000$ GeV² and to determine the evolution of F_2^γ with the factorisation scale.

The determination of F_2^γ uses the fact that the differential cross-section of the $e\gamma$ DIS reaction as a function of Q^2 and Bjorken x is proportional to $F_2^\gamma(x, Q^2)$ ¹. For finite Q^2 the absolute normalisation of F_2^γ cannot be predicted by perturbative QCD and has to be determined from data, but its evolution with Q^2 is predicted by QCD to be logarithmic.

This analysis ² is based on 632 pb⁻¹ of data taken by the OPAL detector in the years 1997–2000, with e^+e^- centre-of-mass energies ranging between 183 and 209 GeV. It extends the measurements of F_2^γ as a function of x up to $\langle Q^2 \rangle = 767$ GeV², and significantly improves on the precision of the measurement of the Q^2 evolution of F_2^γ .

2 Data selection

Three samples of events are studied in this analysis, classified according to the subdetector in which the scattered electron is observed. Electrons are tagged using the SW (33–55 mrad), FD (60–120 mrad) and EE (230–500 mrad) subdetectors. Events are selected by applying cuts on the energy and polar

angle of the scattered electrons and on the invariant mass and multiplicity of the hadronic final state. An anti-tag condition is applied to ensure that the virtuality of the quasi-real photon is small. In addition, for the EE sample an isolation criterion is applied to the tagged electron.

The number of events passing the cuts is 27819, 11874 and 414 for the SW, FD and EE samples respectively. The data range in Q^2 from 7.1–2323 GeV².

3 Results

The analysis presented here addresses two questions: first, the extension of the measurement of F_2^γ as a function of x to the highest possible value of $\langle Q^2 \rangle$ using the EE sample; and second, the evolution of F_2^γ with Q^2 at medium values of x based on all three samples.

Based on the x_{vis} distribution in each range of Q^2 , the structure function F_2^γ has been obtained from the data by unfolding. No attempt has been made in this analysis to access the region of $x < 0.1$, so using a one dimensional unfolding on a linear scale in x is appropriate, in contrast with the previous OPAL analysis of F_2^γ ³. For this purpose the RUN program ⁴ has been used. To obtain the central values the HERWIG 5.9+ k_t (dyn) ⁵ program was used as the input Monte Carlo model to the unfolding.

After subtraction of background, the EE sample has been unfolded on a linear scale in x using three bins in x spanning the range 0.1 – 0.98. Each data point is corrected for radiative effects using the RADEG program ⁶ and bin-centre corrections are applied. The result for F_2^γ/α is shown in Figure 1.

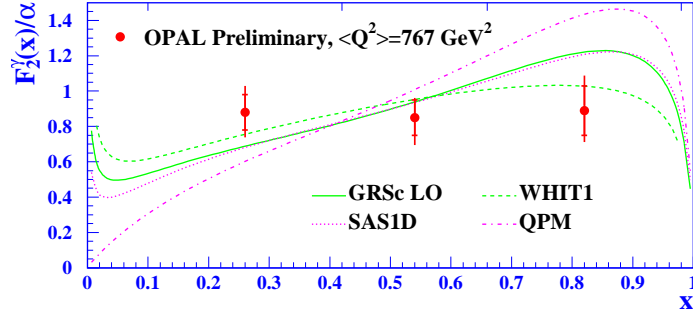


Figure 1. The measured F_2^γ/α as a function of x at $\langle Q^2 \rangle = 767$ GeV². The inner error bars indicate the statistical error and the full bars the total error. The tick marks at the top of the figure represent the bin boundaries.

The evolution of F_2^γ with Q^2 has been measured for several x ranges using all three samples. Due to the large statistics the SW and FD samples are further split into two bins of Q^2 . The data are unfolded separately in each bin of Q^2 and corrected for radiative effects. The results are shown in Figure 2. The data in Figure 2(a) show positive scaling violations in F_2^γ for the x ranges 0.10–0.25 and 0.25–0.60, as predicted by QCD. For the range 0.60–0.85, within statistics, the data are compatible with scaling violations.

To quantify the slope for medium values of x , where data is available at all values of Q^2 , a linear function of the form $a + b \ln Q^2$ has been fitted to the data in the region 0.10–0.60, Figure 2(b). For this investigation the EE sample is also divided into two regions in Q^2 . The result of the fit is

$$F_2^\gamma(Q^2)/\alpha = (0.049 \pm 0.021^{+0.049}_{-0.037}) + (0.139 \pm 0.007^{+0.009}_{-0.013}) \ln Q^2,$$

where Q^2 is in GeV^2 . This is in agreement with the the previous OPAL value ⁷, and the errors on a and b have been strongly reduced.

Both for the measurement of F_2^γ at $\langle Q^2 \rangle = 767 \text{ GeV}^2$ and for the investigation of the Q^2 evolution of F_2^γ , the quark-parton model prediction is not in agreement with the data. It shows a much steeper rise than the data as a function of x for $\langle Q^2 \rangle = 767 \text{ GeV}^2$ and also a different behaviour in the Q^2 evolution. In contrast, the GRSc ⁸, SaS1D ⁹ and WHIT1 ¹⁰ parameterisations of F_2^γ are much closer to the data, with the WHIT1 prediction giving the best description of the data. This means that the corresponding parton distribution functions of the photon are adequate at large values of x and at factorisation scales up to about 1000 GeV^2 .

References

1. R. Nisius, *Phys. Rep.* **332**, 165 (2000).
2. OPAL Collaboration, OPAL Physics Note 489 (31st August 2001).
3. OPAL Collaboration, G. Abbiendi *et al.*, *Eur. Phys. J.* **C18** 15 (2000).
4. V. Blobel, *RUN program manual*, unpublished (1996).
5. G. Marchesini *et al.*, *Comp. Phys. Comm.* **67**, 465 (1992);
The LEP Working Group for Two-Photon Physics, ALEPH, L3, and OPAL, CERN-EP-2000-109.
6. E. Laenen and G.A. Schuler, in *Photon 97*, eds. A. Buijs and F.C. Ern , 57 (World Scientific, 1998).
7. OPAL Collaboration, K. Akerstaff *et al.*, *Phys. Lett.* **B411**, 387 (1997).
8. M. Gl ck, E. Reya, and I. Schienbein, *Phys. Rev.* **D60**, 054019 (1999).
9. G.A. Schuler and T. S jstrand, *Z. Phys.* **C68**, 607 (1995).
10. K. Hagiwara *et al.*, *Phys. Rev.* **D51**, 3197 (1995).

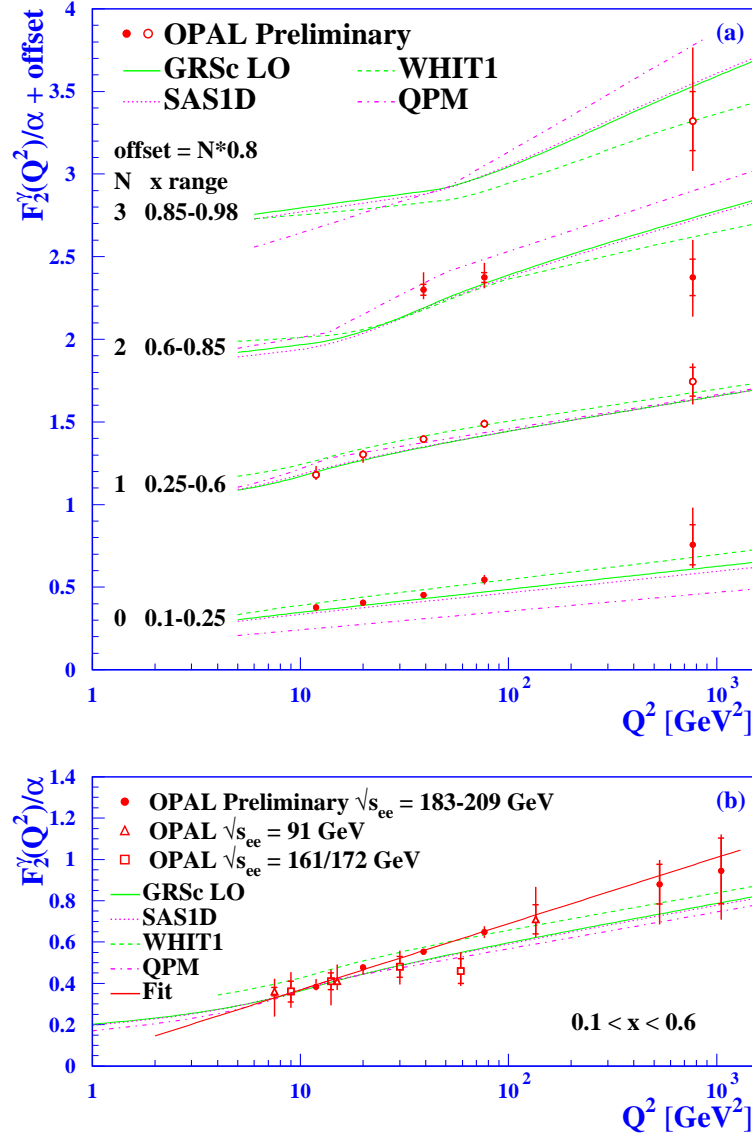


Figure 2. The evolution of F_2^γ/α as a function of Q^2 for several bins of x , (a) 0.10–0.25, 0.25–0.60, 0.60–0.85 and 0.85–0.98 and (b) for the central region 0.10–0.60. The inner error bars indicate the statistical error and the full bars the total error.